Evaluation of the Tellurometer in Highway Horizontal Control Work

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From July 1, 1958, through September 1, 1959, the Tellurometer was used in Mississippi for establishing control over about 439 route miles of highways in 218 working days. Throughout summer and winter operations, a variety of weather conditions and a large range in temperatures were experienced. The measurements were made over all types of topography, throughout sparse and intense land use areas, and along heavily traveled highways.

Based on results attained, the Tellurometer can be relied upon for the establishment of horizontal control to second-order accuracy. Such use of the Tellurometer reduced costs of control surveys to less than 50 percent of the costs of such surveys by conventional triangulation and traverse methods.

●THIS WORK was done by the Photronics Development Division of the Mississippi State Highway Department under the supervision of I.W. Brown. This paper covers a period of 13 months (July 1, 1958 to September 1, 1959) and was initiated under the Bureau of Public Roads and financed with the Highway Planning Survey funds for research projects.

The research has been concerned with the practical application of the Tellurometer and not with its theoretical aspects. The purpose of these research projects was to evaluate the Tellurometer in (a) horizontal control with permanent survey markers established in the State plane coordinate system; and (b) horizontal control for photogrammetric work. These two phases are closely related and for all practical purposes the field methods and operations are the same. Only the cost per mile and coverage are separated into distinct parts for this report.

Some of the field party operations in Mississippi are outlined briefly in this paper. They have been well covered in previous detailed reports. Horizontal control work in Photronics Division is accomplished by five separate operating groups:

1. A reconnaissance party, consisting of either two or three men. It is the responsibility of these men to locate, identify, write a description of and make an overlay plat of all control points to be used in the survey. This includes the location of tower points and selection of the height of tower to be used. All of the surveys are tied to USC&GS triangulation stations which must be found on the ground. The recovery notes for the station markers are sent to USC&GS.
2. A tower party of five men. This party erects and tears down the four Bilby Aluminum towers (two 24 ft and two 37 ft) as required, and sets the permanent survey markers. A 24-ft tower can be built in about 2 hr and a 37-ft tower in about 3 hr. Tear down time averages about 1½ and 2 hr, respectively, for the 24- and 37-ft towers. Towers and station markers are used only on the main scheme centerline surveys.
3. The Tellurometer party of five men, comprising a master operator, two remote operators, a recorder, and a utility man. The utility man drives the truck, and helps hand carry the equipment and set it up and tear it down where required.

4. Two theodolite parties, each consisting of three men, an observer, a recorder, and a light keeper. One party works on main scheme second-order control surveys and the other on third-order supplemental control for photogrammetric mapping operations. These parties use Motorola P-17 portable radios for communication. Much time is saved by the observer having this voice contact with the light keeper, especially when long measurements are being made. Long measurements have ranged up to 35, 000 ft; consequently, some type audible communication must be used.

5. Electronic computations staff. All mathematical computations and adjustments are programmed for and computed by an IBM 650 computer.

These five operating groups were briefly mentioned, as the cost per mile of survey is directly dependent upon the effectiveness and efficiency in which each group performs its part of the work.

The Tellurometer in Mississippi has been used in all parts of the State, covering open farm lands, pastures, densely wooded swamps, tree farms, along and across heavily traveled highways, industrial areas, and thickly populated sections.

It was found that the most difficult and time consuming areas were along the U.S. highways, and at the existing and proposed interchange areas of the larger cities where the traffic counts were as high as 24, 000 vehicles per day. With the use of the Bilby towers, however, the operating time was cut considerably in these areas. One control survey loop along and across US 80 was measured on the ground in 12 field hours and the same loop with the aid of towers was measured in 8 hr.

Throughout the 13 months of Tellurometer operation, the weather conditions varied from bright, sunny, hot days to cold, foggy, overcast days with light mist and rain. Two of the interchanges of I-55 within downtown Jackson were control surveyed at night with good results. Field temperatures ranged from maximums of 16 to 99 F and from minimums of 5 to 22 F, during this period. Probably the most noticeable difference in operational procedures between the extremes of temperature was the instrument warm-up time which increased from the short time of 2 to 3 min in hot weather to as long as 15 to 20 min during the winter months. Another noticeable problem in cold weather was the freezing of the wet bulb of the sling psychrometer and the amount of time required to dissipate the ice before a normal reading could be taken. From such experience it became evident that some work should be done in this field perhaps with alcohol tables.

The work week for the control surveys was five 8-hr days, including all travel time, maintenance time, time lost due to weather, holidays, etc. A period of approximately two weeks covering Tellurometer familiarization, operation, and instrument calibrations was not charged as productive time and is not carried in this report. A man can operate the Tellurometer units after about one day of instruction, but it requires considerable experience on field operations before he is able to select the best sights for optimum operation and to be aware of the capabilities of the instrument. Accuracy and speed of operation are gained with experience. During the past summer, Thomas J. Kennedy, Jr., of the Bureau of Public Roads visited the field crews and timed the Tellurometer operations, when the duration of making several separate set-ups ranged from 12 to 15 min for each one.

The Tellurometer was calibrated once a month and each time maintenance work was performed on it. To accomplish the calibration, two courses are used. One course had been laid out by USCE and is 1, 400 ft long, and the other course is between two first-order triangulation stations 9, 304 ft apart. The instrument measurements of these test courses repeated fairly closely to the correct distances, even under severe weather conditions. Over the 9, 304-ft course the error in Tellurometer measurements ranged to 0. 21 ft and all distance readings were longer than the actual distance. The accuracy of measurement ranged from 1/11, 000 to 1/58, 000, with a mean of approximately 1/26, 000. At the present time a correction of -0. 20 ft is being used for each distance measured between two station markers.

The Tellurometer personnel, with the exception of the utility man, have at least attained a Junior College education and electronic experience in the armed services or civilian electronic occupations. This experience is especially valuable, not from the instrument operation aspects, but for making minor repairs to the instrument in the field. Field maintenance work and down time have been held to a minimum. It is felt that the background of the instrument operators has contributed greatly in this respect.

The Tellurometer has been used for approximately 218 work days. Roughly 75-80 percent of this time has been charged to the Interstate System and the remainder to primary and secondary roads, route relocation, and river control. During this period, approximately 439 highway miles have been control surveyed. All basic horizontal control established by these methods for use in highway centerline staking has been according to specifications set forth by USC&GS for second-order basic control, and for third-order control which is used to control the aerial photographs in photogrammetric work.

For second-order work, 2 coarse and 12 fine readings are taken. Under certain operating conditions such as taking a reading in a deep railroad cut, it was found that certain frequencies tend to "drop out." These readings are omitted and other frequency steps are read.

Permanent survey station markers have been set along approximately 232 mi of highways and all of the 439 mi of project surveys have been control surveyed for mapping photogrammetrically with the Kelsh stereoplotters. Actual traverses measured total 844.85 mi, for an average of 3.87 mi per day.

In accomplishing the horizontal control surveys, a total of 2,555 points were occupied of which 514 were measured to second-order accuracy and 1,169 to third-order accuracy with the Tellurometer, and 872 points were surveyed to third-order accuracy by chaining. The average distance measured between points in the second-order control surveys was 3,641.36 ft, and in the third-order was 2,082.51 ft. The average distance measured by chain to third-order accuracy was 177.43 ft. There was an average of 11.7 points occupied per day or 1.47 points per hour.

The accuracy attained was well within second-order limits, the average being about 1/22,000. The best accuracy achieved with the Tellurometer during these project control surveys was 1/192,000. During October, however, one loop closed to an accuracy of 1/805,000. It should be noted, at this point, that the distance measurements were generally fairly short due to trees and other growth and that the accuracy is very satisfactory. When measuring long distances under optimum weather and topographical conditions, it was found that the Tellurometer is a potential first-order instrument. Good second-order accuracy may be attained under all of the operating conditions encountered so far.

The total cost of the 13 months operation was $107,700. Some of this cost was for non-recurring items such as observation tents, additional tribrachs for the T-2, tripods, tower and ground signal lights, etc, but these items were not deducted and are therefore included in the average cost per mile. Breaking down the total cost between the basic control for centerline staking and supplemental control for photogrammetric mapping is somewhat difficult because there was overlap and duplication of effort in the two separate types of control surveys work. All travel, bad weather, and maintenance time was prorated between the two types of control according to the percent of the total time spent on each. Although the mileage for each type is approximately the same, 69 percent of the total cost was charged to the supplemental control and 31 percent to the basic control. This may seem ambiguous, but several factors enter into these differences in total cost. The objects or ground patterns of which images were selected on the aerial photographs to be position surveyed on the ground as supplemental control points were generally difficult to reach. Instrument pack-in time was increased which reduced the number of instrument set-ups that could be made each day. Also, in all supplemental control surveys work the length of the average distance measurement was approximately 60 percent as long (2,081.51 ft as compared to 3,641.36 ft) as the distance measured in the basic control. Moreover, many of the supplemental control survey measurements were made by chaining distances of less than 500 ft. Thus, $74,300 was charged to supplemental control for an average of $169 per mi; $33,400 was charged to basic control for $76 per mi. The over-all average cost of establishing both basic and supplemental control for 439 linear highway

miles was $245 per mile. This cost is less than 42 percent of the average cost of $589 per mile which was incurred in similar control surveying, by conventional triangulation methods, along 74.5 mi of proposed Interstate Route 10.

CONCLUSIONS

1. The cost per mile of Tellurometer surveyed control is approximately 50 percent that of control surveyed by conventional methods.

2. The speed and accuracy with which horizontal control surveys can be accomplished with the Tellurometer are especially advantageous in making surveys for highways.

3. The Tellurometer can be used under practically all weather, topographic, and land use conditions.